Chapter 3 Strengthening Basic Research Capacity as Foundation of Society 5.0

Basic research explores frontiers of knowledge where no one has gone before; it can break through the limits of existing technologies and provide a source of unprecedented innovations. However, it is difficult to forecast the results due to its nature and the results do not necessarily lead to practical application. However, looking back on history, the prosperity of mankind has been supported by various basic research results, so that it is necessary to further strengthen basic research capacity based on an understanding of its nature.

This chapter overviews Japan's research capacity and explains the challenges that the country faces and its key efforts.

Section 1 Research Capacity of Japan

As of June 2021, the number of Japanese Nobel laureates in the natural sciences (physics, chemistry and physiology/medicine) in this century ranks No.2 in the world (18 laureates) [1] following the United States (See Column 1-6). However, because it takes over 25 years on average from starting research to winning the Nobel Prize in this century[2], the number of laureates does not represent the present research capacity of Japan. Most Nobel laureates conducted important research, which led to the award, in their mid to late 30s. In order to continue to turn out Nobel laureates, it is important to support young researchers.

The numbers of papers in general and papers attracting attention, which are major indicators of research capacity, are declining in international comparison. Twenty years ago, Japan's number of papers ranked No.2 following the United States (average of 1996 to 1998) but it ranks 4th today (average of 2016 to 2018), while the number of papers attracting attention (adjusted top 10% papers) which was 4th 20 years ago is now 9th (Table 1-3-1).

[1] Two of the Japanese laureates in physics, Dr. Nanbu Yoichiro in 2008 and Dr. Nakamura Shuji in 2014, are U.S. citizens.
[2] "Nobel Prize and Science, Technology and Innovation Policy: An analysis for selection process of Nobel Laureates and their scientific career (May 2016)" (Akaike, Hara, Shinohara, Uchino, Nakajima) (SciREX Working Paper #3)

■ Table 1-3-1/Number of papers and number of adjusted top 10% papers by country/region: top 10 countries/regions

All fields	1996-1998 (PY) (Average)		
	Number of papers		
	Fractional counting		
Country/ region name	Number of papers	Share	Ranking
U.S.	202,530	28.9	1
Japan	60,704	8.7	2
UK	49,920	7.1	3
Germany	49,305	7.0	4
France	36,668	5.2	5
Canada	24,799	3.5	6
Italy	23,508	3.4	7
Russia	23,061	3.3	8
China	17,034	2.4	9
Spain	15,509	2.2	10

All fields	2006-2008 (PY) (Average)		
	Number of papers		
	Fractional counting		
Country/ region name	Number of papers	Share	Ranking
U.S.	238,912	24.2	1
China	84,587	8.6	2
Japan	66,460	6.7	3
Germany	55,674	5.6	4
UK	53,735	5.4	5
France	40,733	4.1	6
Italy	34,517	3.5	7
Canada	32,718	3.3	8
India	29,110	2.9	9
Spain	26,447	2.7	10

All fields	2016-2018 (PY) (Average)		
	Number of papers		
	Fractional counting		
Country/ region name	Number of papers	Share	Ranking
China	305,927	19.9	1
U.S.	281,487	18.3	2
Germany	67,041	4.4	3
Japan	64,874	4.2	4
UK	62,443	4.1	5
India	59,207	3.9	6
Rep. of Korea	48,649	3.2	7
Italy	46,322	3.0	8
France	45,387	3.0	9
Canada	41,071	2.7	10

All fields	1996-1998 (PY) (Average)		
	Number of adjusted top 10% papers		
Country/ region name	Fractional counting		
	Number of papers	Share	Ranking
U.S.	30,791	44.0	1
UK	5,880	8.4	2
Germany	4,619	6.6	3
Japan	4,237	6.1	4
France	3,432	4.9	5
Canada	2,939	4.2	6
Italy	1,955	2.8	7
Netherland	1,755	2.5	8
Australia	1,539	2.2	9
Switzerland	1,247	1.8	10

All fields	2006-2008 (PY) (Average)		
	Number of adjusted top 10% papers		
Country/ region name	Fractional counting		
	Number of papers	Share	Ranking
U.S.	35,516	36.0	1
UK	7,086	7.2	2
China	6,598	6.7	3
Germany	6,079	6.2	4
Japan	4,461	4.5	5
France	4,220	4.3	6
Canada	3,802	3.9	7
Italy	3,100	3.1	8
Spain	2,503	2.5	9
Australia	2,493	2.5	10

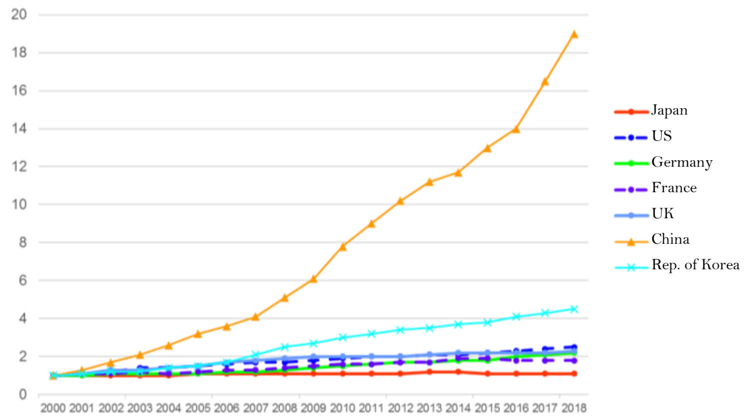
All fields	2016-2018 (PY) (Average)		
	Number of adjusted top 10% papers		
Country/ region name	Fractional counting		
	Number of papers	Share	Ranking
U.S.	37,871	24.7	1
China	33,831	22.0	2
UK	8,811	5.7	3
Germany	7,460	4.9	4
Italy	5,148	3.4	5
Australia	4,686	3.1	6
France	4,515	2.9	7
Canada	4,423	2.9	8
Japan	3,865	2.5	9
India	3,672	2.4	10

Note: The fractional counting method was used. Fractional counting is national counting weighted at the institutional level. For example, if a paper is co-authored by University A in Japan, University B in Japan, and University C in the United States, each institution is given a weight of one-third. The national total is two-thirds for Japan and one-third for the United States. In this manner, one paper is treated as one even if multiple national institutions are involved.

Source: Prepared by MEXT based on the NISTEP "Japanese Science and Technology Indicators 2020"

Declining appeal of becoming a researcher is pointed out as a reason for the declining research capacity. Reasons for declining appeal include the instability of employment due to an increased ratio of limited-term positions for young researchers, the stagnant employment rate[1] of doctoral degree holders and the decreased research time[2] of university teachers. Due to the economic insecurity and uncertain career path, the number of people advancing from master's courses to doctor's courses is declining[3].

■ Figure 1-3-2/Index of University R&D Expenditure, where 1 represents the value for 2000 ■



Note: R&D expenditure are nominal values (converted to OECD purchase power parity)

Source: prepared by MEXT based on the NISTEP "Japanese Science and Technology Indicators 2020"

As of 2018, R&D expenditure of universities that are the main driving force of basic research are 0.9 of the 2000 level in Japan, while the corresponding ratios are 2.5 in the United States, 2.2 in Germany, 1.8 in France, 2.3 in the UK, 19.0 in China and 4.5 in the Rep. of Korea[4].

[1] From MEXT School Basic Survey
[2] From MEXT Survey on to Full-time Equivalent Data at Universities
[3] From MEXT School Basic Survey
[4] NISTEP "Japanese Science and Technology Indicators 2020" Research Material-295, August 2020. The Japanese Science and Technology Indicators 2020 provides as R&D expenditure both the values including personnel costs of all teachers and the values considering full-time equivalent personnel costs of teachers, but this white paper uses as the values of Japan and the graph the latter values provided by the OECD for international comparison.

Intellectual exchange with diverse researchers is necessary to generate ingenious research results. However, the numbers of Japanese researchers going abroad, researchers from overseas accepted by Japanese institutes[1] and their internationally co-authored papers are at a low level[2]. The relative status of Japan in the world's research network has declined. Moreover, participation in new research areas attracting international attention is also stagnant[3].

Other various science and technology data

Science and Technology Indicators
https://www.nistep.go.jp/en/?page_id=52

Science Map 2018
https://www.nistep.go.jp/research/science-and-technology-indicators-and-scientometrics/sciencemap

[1] MEXT commissioned project in 2019 "Survey on Researcher Exchange"
[2] NISTEP "Benchmarking Scientific Research 2019" Survey Material 284, August 2019
[3] NISTEP "Science Map 2018", NISTEP REPORT No. 187, November 2020

Column 1-6 Basic Research Results Becoming a Source of Innovations

Basic research sometimes generates creative results and becomes a source of breakthrough innovations. This column introduces such examples of Nobel Prize laureates of Japan.

(1) Specific Cure for Parasitic Infection (Avermectin)

ŌMURA Satoshi, Distinguished Emeritus Professor of Kitasato University who was awarded the Nobel Prize in Physiology or Medicine in 2015, took an interest in unknown useful natural organic compounds and discovered Avermectin in 1979. Avermectin is a substance produced by a microorganism living in soil collected in Ito city (Shizuoka). It has a strong insecticidal action on parasites (nematode) and mites, but does not act on mammals. Ivermectin, developed based on Avermectin, has become a specific cure for parasitic infections and is taken by hundreds of millions of people to treat parasitic infection in Africa, tropical diseases in Latin America and scabies[1] around the world.

Distinguished Emeritus Professor ŌMURA Satoshi
Provided by Ōmura Satoshi Memorial Institute, Kitasato University

2015 Nobel Prize for Physiology or Medicine
Ōmura Satoshi Memorial Institute
https://www.kitasato-u.ac.jp/lisci/international/OmuraSatoshi.html

(2) Spread of Portable Devices (Lithium-Ion Battery)

YOSHINO Akira, Honorary Fellow of Asahi Kasei Corporation who was awarded the Nobel Prize in Chemistry, invented a lithium-ion battery that is not a single-use primary battery but a secondary battery that can be recharged for repeated use. The invention helped the use of IT[2] devices that could not be used without a power supply to spread very widely, which made a huge contribution to the formation of a digitalized society.

Honorary Fellow YOSHINO Akira
Provided by Asahi Kasei Corporation

Honorary Fellow YOSHINO Akira Special Site, Asahi Kasei Corporation
https://www.asahi-kasei.com/asahikasei-brands/yoshino/

(3) Potential of Regenerative Medicine (iPS[3] Cell)

YAMANAKA Shinya, Director of the Center for iPS Cell Research and Application (CiRA), Kyoto University, received the Nobel Prize in Physiology or Medicine in 2012. He discovered that iPS cells that can differentiate into various cell types can be artificially produced by introducing just four genes into skin cells. It is expected that dysfunctional tissues and organs will be supported or regenerated by using iPS cells. Clinical research for this purpose has already started. The discovery has the potential to save a large number of people through regenerative medicine that recovers lost functions. It is also expected that causes of diseases may be elucidated by producing iPS cells from somatic cells of the patients and making the cells differentiate into diseased cells.

CiRA Director YAMANAKA Shinya
Provided by CiRA, Kyoto University

CiRA, Kyoto University
Learn more about iPS cells
https://www.cira.kyoto-u.ac.jp/e/faq/faq_ips.html

[1] Skin disease caused by itch mites infesting the skin
[2] Information Technology
[3] induced Pluripotent Stem

Section 2 New Projects to Strengthen Research Capacity

In order to strengthen the research capacity of the country, it is important to encourage activities of young researchers including doctoral course students who will play important roles in future research, while at the same time strengthening the financial base of universities that are the main driving force of basic research. For this purpose, the ministry will raise Japan's research universities to the world's highest level, while strongly supporting excellent students so that they can go on to doctoral courses without economic insecurity and tackle ambitious research based on their own intellectual curiosity. Section 2 introduces new initiatives to radically strengthen the research capacity of Japan with this approach.

❶ Establishing the University Endowment Fund with $100 billion

As indicated by the declining international share in high quality papers since the first half of the 2000s, the research capacity of Japan's universities is declining in the world[1]. A vulnerable financial base in international comparison is a restricting factor for universities and should be addressed. In addition, as described above, the ratio of students who go on to a doctoral course is declining due to economic concerns, uncertain career paths and other reasons. In order to change the situation and fundamentally strengthen the research capacity of universities, the government decided to establish the University Endowment Fund with $100 billion. Using the fund's profit, the government will support young talents including doctoral course students stably over a long period of time, while developing university facilities for common use to conduct world-level R&D together with data collaboration infrastructure.

❷ New Initiatives to Improve Treatment of Doctoral Course Students

It is a pressing issue to improve the treatment of doctoral course students so that excellent young people will not give up enrolling in a doctoral course. To this end, "Establishment of University Fellowships towards the Creation of Science Technology Innovation" started in FY2021 separately from the University Fund that requires a certain period of time to produce investment profits. The program supports universities that integrally implement the foundation of a school fellowship system including provision of living expenses (at least 1.8 million yen) to doctoral course students and securing of a career path after completion of the course. Through this program and expansion of the support for doctoral course students with the third supplementary budget of FY2020, the ministry will provide financial support to about 15,000 doctoral course students, which is the government's target.

❸ New Initiatives to Support Challenges of Diverse Researchers with Focus on Young People

For Japan to continue to create research results with a Nobel Prize-level impact in the future, it is

[1] NISTEP "Benchmarking Scientific Research 2019" Survey Material-284, Papers and Share by Sector, P101, August 2019

important that researchers continue to tackle free, challenging and integrated plans not bound by existing frameworks or a short-term-performance-oriented approach. For this purpose, the ministry promotes "Fusion Oriented REsearch for disruptive Science and Technology" to support diverse researchers who are about to or have just become independent researchers with stable research funds up to 10 years and an environment in which they can concentrate on their research in an integrated manner, while at the same time ensuring researcher mobility. Through this program, the ministry aims to deliver results that can bring about disruptive innovations by maximizing the motivation and research time of excellent researchers, while encouraging system reform in research fields to create a better research environment.

Column 1-7 2020 NISTEP Selection (The Researchers with Nice Step)

National Institute of Science and Technology Policy (NISTEP) selects researchers who have made significant contributions to science and technology and inspired Japanese people as "NISTEP Selection (The Researchers with Nice Step)" with a focus on young researchers. Past Researchers with Nice Step include later Nobel laureates YAMANAKA Shinya and AMANO Hiroshi. This column introduces research by two of the "2020 NISTEP Selection."

NISTEP Selection (The Researchers with Nice Step)

URL: https://www.nistep.go.jp/activities/nistep-selection
Source MEXT NISTEP

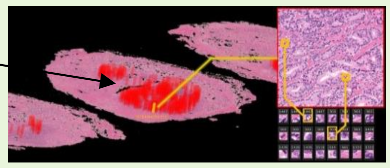
YAMAMOTO Yoichiro, RIKEN Center for Advanced Intelligence Project (AIP)

Team Leader of Pathology Informatics Team, Goal-Oriented Technology Research Group

Title: Developing medical AI technology that discovers new knowledge by itself from cancer images – an epoch-making evolution of cancer recurrence prediction

He developed a medical AI that discovers new knowledge by itself from cancer images. The development realized highly accurate recurrence prediction that discovers new cancer characteristics not noticed by specialists by making AI analyze a large number of microscopic images without doctor's diagnosis information. The method where AI discovers new knowledge from images by itself has the potential for wide applications beyond medical care and is expected to evolve into highly versatile technology.

Red fields are focus of recurrence prediction by AI



AI analysis of prostatic cancer and 3D microscopic images
Provided by RIKEN AIP

SANO Yukie, Assistant Professor, Faculty of Engineering, Information and Systems, University of Tsukuba

Title: Study of Complex Society from the Perspective of Physics - Analysis of Information Spreading Pattern in SNS (Social networking service)

In a new discipline called socio-econophysics, she conducts research to elucidate and predict complex social trends by taking advantage of the knowledge of physics. In recent years, she analyzed blogs and Tweets on the internet and mathematically elucidated that true information and fake information have different characteristics in their spreading patterns. The result is expected to be used for the development of technologies contributing to prevention of spreading of fake information.